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## Agriculture Development Fund

## FINAL REPORT

**STUBBLE HEIGHT AND ROW SPACING CONFIGURATION FOR MAXIMIZING YIELD OF SPRING WHEAT AND CANOLA**

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**Title:** Stubble height and row spacing configuration for maximizing yield of spring wheat and canola

a) **Abstract/Summary:**

In a semiarid environment, the key to securing good crop performance is to use production practices that conserve water and increase water use efficiency. Research on the semiarid prairie has shown that spring wheat grown in tall (12+ inches) cereal stubble averaged about 6% higher yield than when grown in conventional height stubble (6 or 7 inch) and 12% higher than when grown in cultivated stubble. Research on the semiarid prairie has also shown that crops such as spring wheat and canola direct seeded into cereal stubble at a 12-inch row spacing have averaged 12% lower yields than at an 8-inch spacing. To determine the in-crop, interactive effects of stubble height and row spacing on the yield and water use efficiency of spring wheat and canola in the Brown soil zone, we seeded 'AC Barrie' spring wheat and 'Arrow' canola into tall (12+ inches), short (6 inch) and cultivated stubble plots at narrow (8 and 9 inch) and wide (12 inch) row spacings in 1998, 1999, and 2000. We seeded into a medium textured soil near Swift Current. For both canola and wheat, water use within a given year was independent of stubble height and row spacing. For both canola and spring wheat, when averaged across row spacing and year, stubble height had no effect on grain yield or water use efficiency. For canola, when averaged across stubble height and year, grain yield and water use efficiency were greater when seeded in narrow (8 to 9 inch) compared to wide (12 inch) row spacing. For spring wheat, grain yield and water use efficiency were independent of row spacing. These results suggest canola was more sensitive to row spacing than spring wheat. The effects of stubble height and row spacing on yield and WUE were independent and not additive. The important finding from this study is that even in a normally dry to extremely dry climate such as the subarid prairie of southwestern Saskatchewan, when water is abundant, water conservation through canopy manipulation (such as direct seeding into tall stubble and/or seeding in narrow row spacings) does not offer any yield advantages over practices that are less efficient at conserving water such as seeding into cultivated soil and/or in wide row spacings.

b) **Executive Summary:**

This stubble height-row spacing study began in 1998 on a medium textured soil about 8 miles east of the Semiarid Prairie Agricultural Research Centre at Swift Current. The study continued in 1999 and 2000 at the same site. The design features two crops (spring wheat and Argentine canola) seeded in two row spacings (8 and 12-inches) into tall (12+ inches), short (6 to 7 inch), and cultivated stubble plots established just before spring seeding in the stubble of a previous years wheat crop left to overwinter as tall standing stubble. A three year fallow-wheat-crop (wheat or canola) rotation was used to ensure tall stubble for the third year of the rotation (when the treatments were deployed). As expected, there were no treatment effects with regards to total water use. Grain yield, water use efficiency (WUE), biomass and harvest index (HI) were greater for spring wheat compared to canola. When averaged across years and row spacing, stubble height had no significant effect on yields and WUE. In the driest year, 1998, there was a weak pattern for higher yields with direct seeding into standing wheat stubble for both crops. However, in the wetter years or 1999 and 2000, when there was relatively little moisture stress, there was no clear effect of stubble treatment on crop performance. For canola, grain yield and WUE were higher when seeded in narrow (8 and 9 inch) compared to wide (12 inch) rows, whereas for wheat, grain yield and WUE were independent of row spacing. The results from this study, that conflict somewhat with previous research done under drier conditions, indicate that water conservation through canopy manipulation (direct seeding into tall stubble and narrow row spacings) provides significant advantages only when there is significant growing season moisture stress.

c) **Technical Report:**

**Introduction:**

The potential evaporative demand for water usually exceeds the water available to the crop representing the greatest limitation to crop production in the Canadian semiarid prairie. Therefore, in a semiarid environment, the key to securing good economic performance is to use production practices that conserve water and increase water use efficiency. Low disturbance direct seeding into standing cereal stubble is the most effective practice to reduce that limitation for dryland agriculture. Cutforth and McConkey (1997) showed that spring wheat grown in tall (12+ inches) cereal stubble has averaged 6% higher yield and water use efficiency than when grown in conventional height stubble (6 or 7 inch) and 12% higher than when grown in cultivated stubble. However, that research was done with a disc drill on 7-inch row spacing. To successfully seed into tall stubble with more common hoe-type openers generally requires wider row spacings for residue clearance. Preliminary results of research at Swift Current where canola was seeded at 9-inch row spacing showed canola direct seeded into tall standing stubble outyielded canola seeded into cultivated soil by more than 15% (Angadi et al. 2001). McConkey and Miller (1999) showed that, in a water-limited environment, grain yields and water use efficiencies for crops seeded in 12-inch row spacing were generally lower than when seeded in 8-inch row spacing. They found spring wheat was more responsive to row spacing than was canola. They attributed the better performance of the 8-inch row spacing to better water conservation due to quicker closure of the canopy. Therefore the objective of this project was to determine the in-crop effects of stubble height and row spacing on yield and water use efficiency of spring wheat and canola grown in the Brown soil zone.

**Methodology:**

The study was conducted using a randomized complete block design with four replicates. The tall, short, and cultivated stubble treatments were applied to the stubble of wheat grown on the plots the previous year and left to overwinter as tall standing stubble. Stubble treatment plot sizes measured 40 by 48 m. Using a fallow-wheat-crop rotation to ensure tall stubble for the third year of the rotation (when the treatments were deployed), the total land area needed for the experiment was about 9 ha (23 A). Prior to seeding, one plot was cultivated to bury half of the stubble with the remaining residue lying flat on the soil surface (the cultivated treatments). The stubble of another plot was cut with a haybine to an average height of about 15 cm, with the stubble residue spread across the plot (the short stubble treatment). The third plot was left as standing stubble about 35 to 40 cm high (the tall stubble treatment).

Within each stubble treatment, we seeded Barrie spring wheat and Arrow Argentine canola in narrow (8 inch in 1998 and 9-inch in 1999 and 2000) and wide (12 inch) row spacings. Each subplot was 48 m long and about 12 m wide. In 1998, two Versatile/Noble 2000/2200 hoe press drills were used: one at 12-inch and the other drill at 8-inch row spacing. We used the Noble direct-seeding "Eagle Beak" opener with the paired-row attachment. This produced two seed rows about 5-cm apart with all fertilizer placed midway between the seed rows and 3 to 5 cm below the level of the seeds. In 1999 and 2000, we used a self-propelled plot air drill equipped with stealth sideband knife openers to seed the plots. With 9-inch and 12-inch row spacing the seeding width was 6 feet with approximately 2 feet between each pass of the plot air drill.

Weed control and fertilizer application rates were in accordance with recommendations for the area. In 1998, the amount of fertilizer sidebanded at seeding and broadcast shortly after seeding totaled 59 kg N $ha^{-1}$, 53 kg $P_2O_5$ $ha^{-1}$ and 7 kg S $ha^{-1}$. In 1999, the amount of fertilizer sidebanded at seeding and broadcast shortly after seeding totaled 86 kg N $ha^{-1}$, 19 kg $P_2O_5$ $ha^{-1}$ and 38 kg S $ha^{-1}$. In 2000, the amount of fertilizer sidebanded at seeding and broadcast shortly after seeding totaled 69 kg N $ha^{-1}$, 18 kg $P_2O_5$ $ha^{-1}$ and 38 kg S $ha^{-1}$. All nitrogen was applied as ammonium nitrate. Spring and harvest soil water levels were measured gravimetrically to 1.2 m. Evapotranspiration (ET), or water use, from seeding to harvest was calculated using:

ET = (soil water (to 1.2 m) at seeding - soil water at harvest) + growing season precipitation.

Water use efficiencies (WUE) were calculated using:

$$WUE = \text{grain yield} * ET^{-1}.$$

Grain yields were collected in 1998 with a full sized combine and with a plot combine in 1999 and 2000. Other measurements included phenological measurements, plant population, plant height and harvest biomass.

Analysis of variance was conducted for a split-split plot design with year and blocks as main effects, stubble height as sub-plot effects, and row spacing as sub-sub-plot effects. Treatments effects were assessed using LSD. All data were analyzed using JMP version 3.1 (SAS Institute Inc. 1995). Spatially correlated trends were removed using the method described by Basnyat et al. (2000).

**Results:**

1. **Weather**

The first half of the 1998 growing season (to the beginning of July) tended to be slightly warmer than average (Table 1). At seeding, soil water was adequate with the profile filled to above 50% available water. However, from early spring to about mid-June, rainfall was very sparse and the crops grew on stored soil water. Abundant rain fell during the last half of June and the first week of July. Crop conditions at this time were good to excellent but soil water, especially under stubble crops, had been severely depleted. From the first week of July to harvest temperatures were above normal, with maximum temperatures often well above normal, and little rain fell resulting in severe yield reductions because of water stress for crops grown on stubble compared to crops grown on fallow - stubble crops ran out of water early during grain filling. Although the May, June, July (MJJ) precipitation total was similar to the long-term average, low soil water reserves at seeding, the poor distribution of precipitation throughout the growing season, and high temperatures during the latter half of summer resulted in severe stress conditions during critical growth periods, such as heading in wheat and flowering in canola, which reduced grain yields.

For 1999, soil water reserves at seeding were similar to those for 1998. However, MJJ temperatures were much lower and precipitation much higher than in 1998 (Table 1). The distribution of precipitation was more uniform throughout the growing season and stress conditions were minimal during the critical growth period of flowering in both canola and wheat.

For 2000, seedbed moisture was good resulting in good crop establishment. From shortly after seedling emergence (towards the end of May) to mid-June the wheat and canola suffered from water stress because of poor subsurface soil water. Although precipitation has been near the long-term average since the beginning of January 2000, rains during August, September and November of 1999 were much below average resulting in low soil profile water contents. Except for slightly lower maximum temperatures during June, temperatures were near the long-term normals (Table 1). Temperatures tended to be cooler than in 1998 and warmer than in 1999. June precipitation total was substantially less whereas the July precipitation was much greater in 2000 than for 1998 and 1999. Total MJJ precipitation was similar to 1999 and much above the long-term mean.

The yearly differences in temperature and water availability are reflected in crop growth and yield of canola and spring wheat, which responded similarly to weather within a given year. Water use and thus biomass, grain yield and water use efficiency were lowest in 1998, the warmest year as well as the year with the lowest growing season precipitation (Table 2). Water use and yields were much higher in 1999 and 2000 compared to 1998. However, water use was only slightly lower in 1999 compared to 2000 but biomass, grain yield, water use efficiency and harvest index were substantially higher in 1999 than in 2000 because of the cooler growing season temperatures in May and July. Thus, even though precipitation was well above normal during MJJ for both 1999 and 2000, the crops were less stressed during 1999 because of the cooler maximum temperatures (Table 1). Further, within a given year, even though canola and spring wheat tended to use similar amounts of water, biomass and grain yields, water use

efficiency and harvest index tended to be much greater for spring wheat compared to canola (Table 2). We found from past research that, whether grown under irrigation, dryland or imposed drought water regimes in our semiarid climate, compared to canola, spring wheat yielded more grain, yielded similar amounts of biomass, with greater WUE and much greater HI (Angadi et al. 1999). Much of this difference can be attributed to the larger amount of photosynthate required to produce oil in canola than starch in wheat.

2. **Water use**

For both canola and wheat, water use within a given year was independent of stubble height and row spacing, i.e., wheat and canola used the same amount of water regardless of stubble height or row spacing (Table 2). As well, comparing between crops, canola and wheat tended to use similar amounts of water regardless of treatment. These results are consistent with our findings from previous research where water used from seeding to harvest by spring wheat and pulse crops were independent of stubble height (Cutforth and McConkey 1997; Cutforth et al. 1999). This result is not surprising for a semiarid climate. In a water limited environment, water loving crops such as canola and spring wheat tend to 'use' all available water for growth and development. Thus we expected canola and wheat would have similar water use regardless of treatment. It is important to note, that all stubbles overwintered as tall stubble to ensure that all would have equal amount of soil water when the stubble treatments were imposed. In practice, the short stubble would be left form harvest, so this treatment, depending on snow trapping and snowmelt conditions, might have less soil water and thereby less water use, than stubble that overwintered as tall stubble.

3. **Stubble Height**

For both canola and spring wheat, when averaged across row spacing and year, stubble height had no effect on harvest biomass, grain yield or water use efficiency (Table 2). Harvest index (HI) was not affected by stubble height except for canola grown in cultivated stubble with a lower HI than canola grown in short or tall stubble. For both canola and spring wheat, plants grew tallest in the tall stubble but were shortest in the short stubble plots. When averaged across years and row spacing, stubble height had no significant effect on yields and WUE. In the driest year, 1998, there was a weak pattern for higher yields with direct seeding into standing wheat stubble for both crops (Table 3). However, in the wetter years or 1999 and 2000, when overall there was relatively little moisture stress, there was no clear effect of stubble treatment on crop performance. These results conflict with previous research in the semiarid prairie, growing season water use was not affected by stubble height but seeding wheat into tall stubble increased grain yield and water use efficiency by about 12% compared to wheat seeded into cultivated stubble (Cutforth and McConkey 1997). Yield and water use efficiency for wheat seeded into short stubble were intermediate to the other stubble treatments. As well, wheat seeded into tall stubble grew taller than wheat seeded into the cultivated stubble. Further, there was a tendency for spring wheat grown in tall stubble to produce more dry matter. Previous experience studying the effects of stubble heights on crop growth and yield indicated 4 to 5 years of data are needed before obtaining significant results.

Importantly, in wet years, the results indicate that growing crops in tall stubble may not provide any advantage over crops grown in shorter or in cultivated stubble. This is an important result for assessing the areas for which seeding into tall stubble is likely to be a worthwhile management strategy. In the Parkland (Black to Gray soil zones), where moisture stress is typically much less than in the Brown soil zone, seeding into tall stubble may not provide any advantages. In this experiment, the preseeding cultivation may have stimulated some additional N mineralization that benefitted the crops in 1999 and 2000 when applied N fertilizer would have been insufficient to maximize yield given the moisture available for growth. This effect could possibly explain the relatively good yields on cultivated stubble in these wet years. However, we caution that such a possible mineralization benefit from cultivation may not occur for soils in the parkland where the more organic matter-rich soils have greater inherent nitrogen supplying ability under moist conditions than soils of the Brown soil zone.

4. **Row Spacing**

For canola, when averaged across stubble height and year, grain yield, water use efficiency and harvest index were greater when seeded in narrow (8 to 9 inch) compared to wide (12 inch) row spacing (Table 2). Harvest biomass was independent of row spacing whereas plants grew taller when seeded in wide rows. For spring wheat, harvest biomass tended to be greater ($P<0.10$) when seeded in narrow compared to wide row spacing, whereas grain yield, water use efficiency, HI and plant height were all independent of row spacing. These results suggest canola was more sensitive to row spacing than spring wheat. Grain yield and WUE of canola were reduced by about 8% to 9% when seeded in 12 inch rows compared to 8 to 9 inch rows. McConkey and Miller (1999) found spring wheat direct seeded into cereal stubble at a 12-inch row spacing averaged 12% lower yields than at an 8-inch spacing, and spring wheat seeded into tilled soil yielded about 10% lower at a 12-inch row spacing compared to a 8-inch row spacing. They found canola was relatively unaffected by row spacing in both tilled and direct-seeded conditions.

5. **Stubble Height-Row Spacing Interaction**

There was no interaction between stubble height and row spacing. The effects of stubble height and row spacing on yield and WUE were independent and not additive. For canola, grain yield, WUE and HI were generally greater when seeded in narrow compared to wide row spacings across stubble height (Table 4). For wheat, harvest biomass, grain yield, WUE, HI and plant height were independent of row spacing across stubble height. Although harvest biomass tended to be greater for narrow compared to wide row spacing.

**Discussion:**

Direct seeding into standing stubble and, to a lesser degree row spacing, are management practices used to increase water use efficiency in water limited environments such as in the semiarid prairie. Therefore we expect these water conservation practices to be more efficient under conditions where water is limiting (Cutforth and McConkey 1997) and to be less efficient or even detrimental to crop growth and yield when water is abundant (Moulin et al. 1999). In the semiarid prairie of southwestern Saskatchewan, water availability limits crop growth and yield in most years. However, in years when growing season (MJJ) rainfall greatly exceeds the long-term mean, water availability may not be the major limiting factor for crop yields. In 1998 MJJ rainfall was equivalent to the long-term average MJJ rainfall. However, MJJ rainfall was well above average growing season precipitation in 1999 and 2000. MJJ rainfall exceeded average MJJ rainfall by 44% in 1999 and by 51% in 2000. Under these conditions of excess water, water conserving practices from canopy manipulation (tall stubble and/or row spacing) probably would either not affect crop yield or may even be detrimental to crop growth and yield by promoting disease infestations that would reduce yield compared to a crop growing in a conventionally tilled system. Water conservation through in-crop canopy manipulation is more subtle and probably more weather dependent than other methods of water conservation such as snow trapping with tall stubble and avoiding fall tillage. Our experience indicates that at least 4 to 5 years of field data are needed before significant differences occur when comparing direct seeding into standing stubble to seeding into conventionally tilled stubble.

**Summary:**

Historically, water availability is the major limiting factor of crop growth in the semiarid prairie of southwestern Saskatchewan; 1998 was no exception, especially for stubble seeded crops. In a semiarid environment, the key to increasing yields and profitability is to increase water use efficiency. Past research has shown that, generally, stubble height and row spacing are management practices that affect crop response to water stress increasing water use efficiency for spring wheat and pulse crops. However, the results of this study, which contradict somewhat with previous research conducted under drier conditions, indicate that water conserving practices, such as direct seeding into tall standing stubble and/or seeding in narrow rows, do not increase yields when water is abundant but only when water is limited and/or evaporative demand is high.

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Table 1: For 1998-2000, average monthly air temperatures and precipitation for the growing season May through August, as well as the long-term mean (1950-1998) monthly air temperature and precipitation.

| Month | $T_{mx}$ (°C) | | | | $T_{mn}$ (°C) | | | | Precipitation (mm) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1998 | 1999 | 2000 | Long-term mean | 1998 | 1999 | 2000 | Long-term mean | 1998 | 1999 | 2000 | Long-term mean |
| May | 20.1 | 15.4 | 17.5 | 17.4 | 5.0 | 4.4 | 4.3 | 4.2 | 37 | 71 | 65 | 42 |
| June | 19.5 | 19.4 | 19.8 | 21.8 | 8.4 | 8.9 | 8.0 | 8.9 | 81 | 93 | 54 | 73 |
| July | 27.0 | 22.7 | 25.3 | 25.4 | 13.3 | 10.2 | 13.0 | 11.3 | 48 | 70 | 127 | 48 |
| | | | | | | | | MJJ total | 165 | 234 | 246 | 163 |
| August | 28.8 | 26 | 25.7 | 24.9 | 13.1 | 11.7 | 11.3 | 10.5 | 35 | 10 | 13 | 41 |

Table 2: For the specified crop when averaged across all other treatments and when averaged across 1998-2000, effect of treatment (either stubble height or row spacing) and year on water use (mm), yield (kg $ha^{-1}$), water use efficiency (WUE - kg $ha^{-1}$ $mm^{-1}$) and biomass (kg $ha^{-1}$), and for harvest index (HI) when averaged across 1999-2000. Row spacing has been designated narrow (8 inches in 1998 and 9 inches in 1999, 2000) and wide (12 inches).

| Crop | Treatment or Year | Water* use (mm) | Grain yield (kg $ha^{-1}$) | WUE (kg $ha^{-1}$ $mm^{-1}$) | Biomass† (kg $ha^{-1}$) | HI | Plant Height (cm) |
|---|---|---|---|---|---|---|---|
| Canola | Cultivated | 289 | 1467 | 4.91 | 5523 | 0.245b | 112ab |
| | Short | 288 | 1454 | 5.09 | 5595 | 0.254a | 109b |
| | Tall | 294 | 1432 | 4.93 | 5625 | 0.255a | 113a |
| Wheat | Cultivated | 290 | 2216 | 7.53 | 5952 | 0.346 | 92ab |
| | Short | 288 | 2074 | 7.2 | 5951 | 0.346 | 91b |
| | Tall | 288 | 2206 | 7.58 | 6103 | 0.347 | 93a |
| Canola | narrow | 291 | 1513a | 5.16a | 5615 | 0.254a | 110b |
| | wide | 290 | 1389b | 4.80b | 5547 | 0.248b | 113a |
| Wheat | narrow | 286 | 2170 | 7.4 | 6088A | 0.346 | 92 |
| | wide | 290 | 2160 | 7.47 | 5916B | 0.346 | 93 |
| Canola | 1998 | 232c | 996b | 4.38C | 4904b | | 114a |
| | 1999 | 305b | 1718a | 5.70a | 6558a | 0.269a | 108b |
| | 2000 | 333a | 1638a | 4.85b | 5281b | 0.234b | 112ab |
| Wheat | 1998 | 234b | 1406c | 6.02b | 4208c | | 84b |
| | 1999 | 307a | 2948a | 9.63a | 7962a | 0.356a | 98a |
| | 2000 | 324a | 2142b | 6.66b | 5836b | 0.336b | 95a |

*Single degree of freedom within cell comparisons: no letters, no significant differences; small (Capital) letters indicate significant differences at $P<0.05$ ($P<0.10$).

†Biomass yield determined from hand harvested samples.

Table 3: For 1998 to 2000, water use (mm), yield (kg $ha^{-1}$), water use efficiency (WUE - kg $ha^{-1}$ $mm^{-1}$) and biomass (kg $ha^{-1}$), and for 1999-2000, harvest index (HI) of canola and wheat grown in cultivated, short, and tall stubble and averaged across row spacing in 1998, and averaged across row spacing and year for 1999 and 2000.

| Crop | Year | Stubble Height | Water* use (mm) | Grain yield (kg $ha^{-1}$) | WUE (kg $ha^{-1}$ $mm^{-1}$) | Biomass† (kg $ha^{-1}$) | HI | Plant Height (cm) |
|---|---|---|---|---|---|---|---|---|
| Canola | 1998 | Cultivated | 231 | 937 | 4.09 | 4823 | | 112 |
| | | Short | 232 | 1030 | 4.61 | 4889 | | 113 |
| | | Tall | 234 | 1020 | 4.45 | 5001 | | 118 |
| | 1999-2000 | Cultivated | 318 | 1682 | 5.32 | 5873 | 0.245 | 112 |
| | | Short | 316 | 1679 | 5.34 | 5948 | 0.255 | 108 |
| | | Tall | 324 | 1670 | 5.18 | 5938 | 0.255 | 111 |
| Wheat | 1998 | Cultivated | 232 | 1352 | 5.84 | 4098 | | 83 |
| | | Short | 235 | 1412 | 6.01 | 4273 | | 85 |
| | | Tall | 235 | 1454 | 6.22 | 4253 | | 84 |
| | 1999-2000 | Cultivated | 319 | 2648a | 8.38 | 6880 | 0.346 | 98 |
| | | Short | 314 | 2405b | 7.79 | 6790 | 0.346 | 95 |
| | | Tall | 315 | 2582ab | 8.27 | 7027 | 0.347 | 98 |

*Single degree of freedom within cell comparisons: no letters, no significant differences; small letters indicate significant differences at P<0.05 .

†Biomass yield determined from hand harvested samples.

Table 4: For 1998-2000, water use (mm), yield (kg $ha^{-1}$), water use efficiency (WUE - kg $ha^{-1}$ $mm^{-1}$) and biomass (kg $ha^{-1}$), and for 1999-2000, harvest index (HI) of canola and wheat grown in cultivated, short, and tall stubble at narrow (8 inches in 1998 and 9 inches in 1999, 2000) and wide (12 inch) row spacing.

| Crop | Stubble height | Row Spacing | Water* use (mm) | Grain yield (kg $ha^{-1}$) | WUE (kg $ha^{-1}$ $mm^{-1}$) | Biomass† (kg $ha^{-1}$) | HI | Plant Height (cm) |
|---|---|---|---|---|---|---|---|---|
| Canola | Cultivated | narrow | 287 | 1499a | 5.16a | 5569 | 0.248a | 110 |
| | | wide | 291 | 1367b | 4.66b | 5476 | 0.242b | 113 |
| | Short | narrow | 289 | 1510A | 5.2 a | 5601 | 0.257A | 108B |
| | | wide | 288 | 1415B | 4.99a | 5589 | 0.252B | 111A |
| | Tall | narrow | 296 | 1527a | 5.11A | 5674 | 0.258a | 113 |
| | | wide | 292 | 1379b | 4.76B | 5577 | 0.251b | 114 |
| Wheat | Cultivated | narrow | 289 | 2233 | 7.51 | 5986 | 0.345 | 92 |
| | | wide | 290 | 2198 | 7.55 | 5919 | 0.347 | 93 |
| | Short | narrow | 282 | 2066 | 7.17 | 6049 | 0.345 | 90 |
| | | wide | 293 | 2081 | 7.22 | 5852 | 0.346 | 92 |
| | Tall | narrow | 288 | 2212 | 7.51 | 6228 | 0.348 | 93 |
| | | wide | 288 | 2201 | 7.65 | 5977 | 0.346 | 94 |

*Single degree of freedom within cell comparisons: no letters, no significant differences; small (Capital) letters indicate significant differences at P<0.05 (P<0.10).

†Biomass yield determined from hand harvested samples.